Preventing ventilator-associated pneumonia a mixed-method study to find behavioral leverage for better protocol adherence

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Abstract: OBJECTIVE Preventing ventilator-associated pneumonia (VAP) is an important goal for intensive care units (ICUs). We aimed to identify the optimal behavior leverage to improve VAP prevention protocol adherence. DESIGN Mixed-method study using adherence measurements to assess 4 VAP prevention measures and qualitative analysis of semi-structured focus group interviews with frontline healthcare practitioners (HCPs). SETTING The 6 ICUs in the 900-bed University Hospital Zurich in Zurich, Switzerland.Patients and participantsAdherence to VAP prevention measures were assessed in patients with a device for invasive ventilation (ie, endotracheal tube, tracheostomy tube). Participants in focus group interviews included a convenience samples of ICU nurses and physicians. RESULTS Between February 2015 and July 2017, we measured adherence to 4 protocols: bed elevation showed adherence at 27% (95% confidence intervals [CI], 23%-31%); oral care at 41% (95% CI, 36%-45%); sedation interruption at 81% (95% CI, 74%-85%); and subglottic suctioning at 88% (95% CI, 83%-92%). Interviews were analyzed first inductively according a grounded theory approach then deductively against the behavior change wheel (BCW) framework. Main behavioral facilitators belonged to the BCW component 'reflective motivation' (ie, perceived seriousness of VAP and self-efficacy to prevent VAP). The main barriers belonged to 'physical capability' (ie, lack of equipment and staffing and side-effects of prevention measures). Furthermore, 2 primarily technical approaches (ie, 'restructuring environment' and 'enabling HCP') emerged as means to overcome these barriers. CONCLUSIONS Our findings suggest that technical, rather than education-based, solutions should be promoted to improve VAP prevention. This theory-informed mixed-method approach is an effective means of guiding infection prevention efforts.

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Original Article

Preventing ventilator-associated pneumonia—a mixed-method study to find behavioral leverage for better protocol adherence

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Abstract

Objective: Preventing ventilator-associated pneumonia (VAP) is an important goal for intensive care units (ICUs). We aimed to identify the optimal behavior leverage to improve VAP prevention protocol adherence.

Design: Mixed-method study using adherence measurements to assess 4 VAP prevention measures and qualitative analysis of semi-structured focus group interviews with frontline healthcare practitioners (HCPs).

Setting: The 6 ICUs in the 900-bed University Hospital Zurich in Zurich, Switzerland.

Patients and participants: Adherence to VAP prevention measures were assessed in patients with a device for invasive ventilation (ie, endotracheal tube, tracheostomy tube). Participants in focus group interviews included a convenience samples of ICU nurses and physicians.

Results: Between February 2015 and July 2017, we measured adherence to 4 protocols: bed elevation showed adherence at 27% (95% confidence intervals [CI], 23%–31%); oral care at 41% (95% CI, 36%–45%); sedation interruption at 81% (95% CI, 74%–85%); and subglottic suctioning at 88% (95% CI, 83%–92%). Interviews were analyzed first inductively according a grounded theory approach then deductively against the behavior change wheel (BCW) framework. Main behavioral facilitators belonged to the BCW component 'reflective motivation' (ie, perceived seriousness of VAP and self-efficacy to prevent VAP). The main barriers belonged to 'physical capability' (ie, lack of equipment and staffing and side-effects of prevention measures). Furthermore, 2 primarily technical approaches (ie, 'restructuring environment' and 'enabling HCP') emerged as means to overcome these barriers.

Conclusions: Our findings suggest that technical, rather than education-based, solutions should be promoted to improve VAP prevention. This theory-informed mixed-method approach is an effective means of guiding infection prevention efforts.

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Intensive care unit (ICU) patients are at high risk for developing healthcare-associated infections, and ventilator-associated pneumonia (VAP) is the most common of these infections.[1] VAP is defined as pneumonia occurring 48 h following endotracheal intubation with the ventilator being in place the date of event or the day before.[2] The incidence of VAP was reported to be as high as 42%,[3–5] but estimates vary substantially depending on different diagnostic scoring systems.[3,6] Also, VAP is associated with substantial morbidity, an increase in mortality, and excess costs.[7,8]

Multiple international guidelines regarding the prevention of VAP are available.[9–13] Most hospitals implement VAP prevention elements as part of a prevention bundle, but the components of such bundles may vary from hospital to hospital.[14] Unfortunately, sufficient evidence about the efficacy of single bundle components in preventing VAP is lacking.[14] Some prevention measures, such as oral care with chlorhexidine, have recently come under suspicion as being potentially harmful.[15,16] Nevertheless, the potential to decrease VAP rates using VAP prevention bundles has been demonstrated by many authors,[17–22] and the preventable proportion of VAP was estimated to be 52%–55%.[23,24]

Effective implementation is as important as choosing the right bundle components.[14] Adherence to and knowledge about VAP prevention measures were shown to be poor in several studies.[19,25,26] Adherence can be raised through different implementation programs.[19,27] A systematic review identified education (eg, training sessions or development of concise summaries of the evidence) and execution strategies (eg, standardization of care processes and building redundancies into routine care) as strategies to enhance the adoption of VAP prevention measures.[28] These authors also mentioned multidisciplinary teamwork, involvement of champions, and networking among peers as engagement strategies.[28] Another systematic review showed that improvement in adherence to preventive measures occurred once audit and feedback of adherence rates with or without reminder systems were introduced in addition to organizational change efforts and education of frontline healthcare practitioners (HCPs).[29] Generally, it is well accepted that theory-based implementation strategies are more effective in achieving sustained behavior changes.[30]

In our hospital, a 9-element VAP bundle was designed in 2011 by an interprofessional working group. Implementation of the bundle began in 2013. In February 2015, the hospital infection prevention and control (IPC) team measured adherence to

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selected bundle elements and found suboptimal overall adherence rates. Therefore, the IPC team chose a mixed-methods approach to assess adherence to VAP prevention measures and identify barriers to and facilitators of protocol adherence.

Methods

Setting

The study took place at the University Hospital Zurich (UHZ), Zurich, Switzerland, a 900-bed tertiary-care teaching hospital featuring all medical specialties except pediatrics and orthopedics. In total, the study included 64 beds in 6 ICUS: medical ICU, general thoracic and transplant surgery ICU, trauma ICU, burn ICU, cardiac surgery ICU, and neurosurgery ICU.

The University Hospital Zurich (UHZ) VAP bundle

The UHZ VAP bundle was created by an interprofessional group comprising IPC team members, ICU nurses and physicians, and anesthesiologists. It included 9 elements: (1) continuous application of a sedation and weaning protocols with daily sedation interruptions; (2) head of the bed elevation of ≥30°; (3) oral decontamination with chlorhexidine mouth wash twice daily; (4) the use of endotracheal tubes with continuous subglottic secretion drainage; (5) hand hygiene according to the WHO Five Moments concept[31]; (6) use of noninvasive ventilation (NIV) whenever feasible; (7) periodic changes of ventilator tubing and filters biweekly; (8) use of closed suction systems; and (9) daily evaluation of stress ulcer prophylaxis to limit its use. The bundle was enacted by the medical director in 2011, and the standard operating procedure (SOP) was made accessible via the hospital's intranet. In 2013, the UHZ VAP bundle was formally implemented under the lead of ICU nurses by providing education and practical training. In June 2016, an 'action month,' 5 of the 9 bundle elements (ie, head of bed elevation, oral care with chlorhexidine, hand hygiene, NIV, closed suction system) were again addressed by providing education, practical training, contests, and posters and stickers as reminders. The elements were chosen by the ICU teams based on feedback adherence rates and the anticipated need for training.

Adherence measurements

Adherence to VAP prevention elements was assessed by overt, nonparticipatory observations in February 2015 (measurement 1), in August 2015 (measurement 2), in July 2016 (measurement 3) and continuously from July to September 2017 (measurement 4). Investigators visited all ICUs once or twice daily during weekdays between 8 AM and 6 PM. We evaluated 4 bundle elements whose execution relied on HCP decision making rather than on standardized workflows. (1) Daily sedation interruption was assessed by reviewing the handwritten tracking sheet and by oral confirmation by the responsible nurse. We excluded patients with severe hemodynamic shock, a subset of specified intracranial injuries or neurologic diseases that challenge cerebral perfusion, extracorporeal membrane oxygenation, neuromuscular blocking agents, and therapeutic hypothermia, as well as those in need of a kinetic bed system. (2) Head of bed elevation was measured using a Smartphone application for angle measurement (Mammut Safety APP, version 1.0, Mammut Sports Group AG, Seon, Switzerland). We excluded patients with hemodynamic instability, instable spinal or pelvic fracture, and specific intracranial injuries or neurologic diseases that impair cerebral perfusion pressure. (3) Twice-daily oral care with chlorhexidine was assessed by review of the electronic patient record. (4) Continuous subglottic secretion drainage was assessed by direct observations. We excluded patients with endotracheal or tracheostomy tubes not featuring a suction port. In measurement 2, sedation interruption and subglottic drainage were not assessed. In measurement 4, subglottic drainage was not assessed. Good, intermediate, and poor adherence were defined as ≥80%, ≥50%–80%, and <50% adherence, respectively.

Theoretical framework

The behavior change wheel (BCW) is a theoretical framework that incorporates several existing behavior-change frameworks into a behavioral system (COM-B) composed of 3 'sources of behavior': capability, opportunity, and motivation.[32] The BCW was chosen to guide the analysis in this study because it is an overarching framework that considers the influence of context on individual behavior. A further advantage of the BCW is that it links barriers and facilitators identified within the COM-B system to proposed interventions that may be effective in addressing deficits (Table 1).

Focus group interviews—Data collection and analysis

The 6 focus group interviews, 1 per ICU, were conducted between May 4 and June 5, 2015. We used a purposeful criterion sampling approach,[33] and we sought to include both nurses and physicians from each of the 6 ICUs to gather a broad range of experiences related to VAP prevention. Beyond these criteria, participants included convenience samples of ICU nurses and physicians on duty who were available when the group interview took place. They represent a subset of the observed HCP. All semi-structured interviews were conducted by the same IPC nurse (M.T.M.). The interview guide is shown in Table 2. Written informed consent was obtained from all interviewees. Interviews were held in Swiss-German, audiotaped, and transcribed verbatim. Following a grounded theory approach, initial data analysis was conducted inductively by 2 investigators (A.W. and M.T.M.) to summarize interview content and to inform the ongoing data collection.[34] Following data collection, the same 2 investigators (A.W. and M.T.M.) deductively coded all identified barriers and facilitators according to the BCW behavioral system components: capability, opportunity, or motivation.[32] Any discrepancies in coding were resolved by a health psychologist (L.C.). Using the same approach, participant ideas for better bundle implementation approaches were deductively coded according to the intervention functions of the BCW with its 9 components: education, persuasion, incentivization, coercion, training, restriction, environmental restructuring, modeling, and enablement. These participant suggestions were then compared with the intervention functions proposed by the BCW for addressing identified barriers and facilitators (Table 1).

Results

Adherence measurements

Data regarding adherence rates are shown in Table 3. Adherence was poor for head of bed elevation (27%; 95% confidence intervals [CI], 23%–31%) and oral care (41%; 95% CI, 36%–45%), though it was good for daily sedation interruption (81%; 95% CI, 74%–85%) and subglottic suctioning (88%; 95% CI, 83%–92%). A considerable number of patients had a contraindication for head of bed elevation (27%; 95% CI, 23%–31%) and sedation interruption (41%; 95% CI, 36%–46%). Also, 41% (95% CI, 36%–46%)

Table 1. Links Between Components of the 'COM-B' Model of Behavior and Intervention Functions[a]

	Intervention functions								
Source of Behavior	Education	Persuasion	Incentivization	Coercion	Training	Restriction	Environmental Restructuring	Modeling	Enablement
Physical capability[b]					√				√
Psychological capability[c]	√				√				√
Reflective motivation[d]	√	√	√	√					
Automatic motivation[e]		√	√	√			√	√	√
Physical opportunity[f]						√	√		√
Social opportunity[f]						√	√		√

[a]Table reproduced with permission from Michie et al.[32]
[b]Physical capability can be achieved through physical skill development, which is the focus of training, or potentially through enabling interventions such as medication, surgery or prostheses.
[c]Psychological capability can be achieved through imparting knowledge or understanding; training emotional, cognitive, and/or behavioral skills; or through enabling interventions such as medication.
[d]Reflective motivation can be achieved through increasing knowledge and understanding or through eliciting positive (or negative) feelings about behavioral target.
[e]Automatic motivation can be achieved through associative learning that elicits positive (or negative) feelings and impulses and counterimpulses relating to the behavioral target, imitative learning, or habit formation that directly influences automatic motivational processes (eg, via medication).
[f]Physical and social opportunity can be achieved through environmental change.

Table 2. Semi-Structured Interview Guide

Introducing Question	Deepening Question
1. What crosses your mind when you hear the term VAP?	How many patients do you estimate, suffer from VAP on your ICU?
2. Do you think VAP is preventable?	To what extent VAP is preventable?
3. Do you know the elements of the VAP bundle in this hospital?	
4. For which bundle elements is adherence good or poor?	What do you perceive as facilitators and barriers to adherence with the bundle elements?

Note. VAP, ventilator-associated pneumonia.

of patients did not have a tube with a suction port for subglottic suctioning.

Focus group interviews

Overall, 42 nurses and 4 physicians participated in the interviews (Table 4); of these, 17 were male (37%). One participant withdrew consent because the interview was audiotaped. The interviews lasted between 35 and 45 minutes. We determined that data saturation was achieved (ie, no new barriers and facilitators were being identified[35] after the fourth focus group), but we continued data collection based on our criterion sampling strategy until all ICUs had been included.

Barriers and facilitators for adherence to the VAP bundle according to the BCW sources of behavior

At the center of the BCW framework lie the 'sources of behavior', 6 essential components that shape behavior: physical and psychological capability, reflective and automatic motivation, and physical and social opportunity.[32] The interviewee's statements about barriers and facilitators for adherence to the prevention measures were coded according to these components (Table 5). A total of 104 statements were coded: 79 (76%) referred to barriers and 25 (24%) to facilitators. The most commonly coded components were 'physical opportunity' with 49% of statements (n = 51: 47 barriers and 4 facilitators), followed by 'reflective motivation' with 21% (n = 22: 9 barriers and 13 facilitators), 'automatic motivation' with 12% (n = 12: 11 barriers and 1 facilitator), and 'psychological capability' with 10% (n = 10: 5 barriers and 5 facilitators) of statements, respectively. 'Social opportunity' and 'physical capability' appeared rarely, in 7% (n = 7) and 2% (n = 2), respectively.

Physical and psychological capability

'Physical capability', which is defined as the individual's physical capacity to engage in the activity, was brought up as a barrier once, referring to the inability to estimate the correct angle of head of bed elevation by eye. 'Psychological capability,' like self-discipline, was mentioned as a facilitator. Lack of knowledge and forgetfulness were brought up as barriers several times.

Reflective and automatic motivation

Most facilitators were related to the 'reflective motivation' BCW component, defined as 'evaluations and plans that energize and direct behavior.' Interviewees were aware of the frequency and consequences of VAP and generally considered prevention measures useful to lower VAP rates. Some HCPs, however, mentioned doubts about the effectiveness of certain prevention measures like head of bed elevation and noninvasive ventilation, which may have presented a barrier to adherence. Numerous barriers belonged to the 'automatic motivation' component, that is, emotions and impulses that direct behavior. HCPs were concerned about prevention measures affecting the patient's well-being, such as disturbance by the noise of the subglottic suctioning device, uncomfortable body position due to head of bed elevation, and unpleasant taste of the chlorhexidine mouth wash.

Physical and social opportunity

Most barriers were assigned to the group of 'physical opportunity' and, less commonly, 'social opportunity'—factors that lie outside the individual HCP. Three points emerged as being most important: (1) lack of equipment (eg, tracheal tubes with suction port for subglottic suctioning, chlorhexidine gel instead of mouth wash, beds with appropriate angle measurement devices), (2) lack of adequate staffing or time for patient care, and (3) competing priorities of

Table 3. Quantitative Adherence Rates to VAP Prevention Measures

Bundle Element	Measurements (No. of observations)	% Adherence in Patients Without Contraindications (95% CI)	% Patients With Contraindication of All Patients (95% CI)
Head of bed elevation	1: February 2015 (n = 235)	23 (17–30)	19 (14–24)
	2: August 2015 (n = 134)	16 (9–24)	24 (17–32)
	3: July 2016 (n = 78)	50 (34–66)	46 (35–58)
	4: July 2017 (n = 194)	32 (25–40)	18 (12–24)
	Overall (n = 641)	**27 (23–31)**	23 (20–26)
Sedation interruption	1: February 2015 (n = 68)	81 (65–92)	46 (33–58)
	2: August 2015	N/A	N/A
	3: July 2016 (n = 58)	63 (44–80)	48 (35–62)
	4: July 2017 (n = 103)	88 (78–94)	27 (19–37)
	Overall (n = 229)	**81 (74–87)**	38 (32–45)
Oral care	1: February 2015 (n = 126)	43 (34–52)	N/A
	2: August 2015 (n = 116)	38 (29–47)	N/A
	3: July 2016 (n = 73)	30 (20–42)	N/A
	4: July 2017 (n = 169)	46 (38–53)	N/A
	Overall (n = 484)	**41 (36–45)**	N/A
Subglottic suctioning	1: February 2015 (n = 236)	90 (84–95)	45 (38–52)[a]
	2: August 2015	N/A	N/A
	3: July 2016 (n = 140)	86 (77–92)	34 (26–43)[a]
	4: July 2017	N/A	N/A
	Overall (n = 222)	**88 (83–92)**	41 (36–46)[a]

Note. CI, confidence interval; N/A, not applicable.
[a]"Contraindication" for subglottic suctioning: no tube with suction port.

Table 4. Focus Group Interview Participants

Type of ICU	No. of Nurses	No. of Physicians	Total	Male Participants, No. (%)
Burn ICU	4	0	4	2 (25)
Medical ICU	6	0	6	3 (50)
Thoracic and transplant surgery ICU	9	0	9	1 (11)
Neurosurgery ICU	9	1	10	4 (40)
Cardiac surgery ICU	8	2	10	4 (40)
Trauma ICU	6	1	7	3 (43)
Total	42	4	46	17 (37)

Note. ICU, intensive care unit.

patients and prevention measure (eg, head of bed elevation not possible due to the increased need for catecholamines or sedation interruption increasing intracranial pressure). Only rarely did HCPs mention the available infrastructure as a facilitator for bundle adherence. For 'social opportunity,' or the cultural milieu, champions were brought up as facilitators and lack of hierarchical support was mentioned as barrier for bundle adherence.

Intervention ideas according to the BCW intervention functions

The spontaneously mentioned ideas to improve bundle adherence were provision or improvement of equipment, which we mapped to the 'environmental restructuring' component. The introduction of a device to indicate head of bed elevation and tracheal

Table 5. Barriers and Facilitators Identified From the Focus Group Interviews Mapped According to the Behavior Change Wheel Framework

Sources of Behavior Components	Subdivision	Description	Barriers: Typical Quotes From the Interviews	Facilitators: Typical Quotes From the Interviews
Capability	Physical	Individual's physical capability to engage in the behavior	Female nurse: "30° is very steep indeed. We often underestimated how steep 30° is." (inability to estimate angle)	N.A.
	Psycho-logical	Individual's psychological capability (eg, comprehension, reasoning) to engage in the behavior	Male physician: "We do oral care with chlorhexidine..." - checks back with the group: "Yes, we do. Is this [an] official [prevention measure]?" (lack of knowledge) Male nurse: "Sometimes people forget one or the other thing." (forgetfulness)	Male nurse: "I think we have to … bring the subject over and over back into our minds to not forget to apply the prevention measures." (self-discipline, awareness)
Motivation	Reflective	Evaluations or plans that energize and direct behavior	Male physician: "This head of bed elevation... the beneficial effect is not really proven, right?" (lack of evidence) Female nurse: "The patients with noninvasive ventilation, they are often struggling ... they swallow air, then burp and then aspirate." (perceived inefficacy of prevention measure)	Male physician: "VAP is one of the most common nosocomial infections in the ICU." (perceived importance of VAP) Female nurse: "I do believe we can prevent VAP—at least 50% of VAP are preventable, or even more!" (perceived preventability of VAP)
	Automatic	Emotions and impulses that that energize and direct behavior	Female nurse: "... this continuous subglottic drainage ... to hear this noise 24h a day ... that is a nuisance for the patients." (perceived conflict with patient's well-being) Female nurse: "We do turn our patients to the side. Then, head of bed elevation to 30° is really uncomfortable." (perceived conflict with patient's well-being)	Female nurse: "Oral care with chlorhexidine … I do that all the time, automatically." (habit)
Opportunity	Social	Cultural milieu outside the individual that make the behavior possible or prompt it	Female nurse: "Head of bed elevation and mobilization of the patient is really important, and I find it too bad that we don't get support from our head nurse to do it properly – and get enough time for that." (hierarchical structures, social influence) Male nurse: "To decide about contraindications is in the decision power of the physician team [vs the nurse team]." (professional role and responsibilities)	Male nurse: "This one surgeon, Dr. S., he is really strict. He wants all his patients to have head of bed elevation of more than 30°, always." (champions)
	Physical	Environment outside the individual that make the behavior possible or prompt it	Female nurse: "I left patients intubated on the ventilator overnight [even though they were ready to extubate] because I was responsible for 2 patients." (lack of staffing/time) Female nurse: "… head of bed elevation of 30° or higher is important. [But] this is often not possible, if the patient has a high amount of catecholamines running." (side effects of prevention measures) Male nurse: "I do not understand why we do not have a tracheostomy tube with a subglottic suction system." (barrier: lack of devices) Male nurse: "This oral care... when the patients are not deeply sedated, they just swallow the chlorhexidine, and off it goes...!" (feasibility)	Male nurse: "You know, they do not save money for technical things ... all our patients now do have this machine for subglottic suctioning." (infrastructure/ equipment)

Note. ICU, intensive care unit; VAP, ventilator-associated pneumonia.

tubes with ports for subglottic suctioning were most often mentioned. Second, alarm systems as reminders were mentioned several times, predominantly in the context of head of bed elevation, which we mapped to the components 'environmental restructuring' and 'HCP enabling.' Third, introduction of protocols and checklist for the bundle in general and for sedation interruption specifically were brought up, which belong to the components 'restriction' and 'HCP enabling,' respectively. Table 6 outlines observed adherence measures, self-reported adherence rates, and barriers, facilitators, and intervention ideas according the BCW for every VAP bundle component.

Discussion

This mixed-method study measured adherence to 4 VAP prevention measures and found poor adherence to head of bed elevation and oral care and good adherence to sedation vacation and subglottic suctioning. Corresponding to the BCW 'sources of behavior,' facilitators for adherence belonged primarily to the component 'reflective motivation': perceived seriousness of VAP and self-efficacy to prevent VAP. Barriers mainly belonged to the BCW component 'physical capability': lack of equipment and staffing and side-effects of prevention measures. To improve

Table 6. Outline of Self-Reported Versus Measured Adherence Rates, Mapped Barriers and Facilitators, and Intervention Opportunities

	Observed Overall Adherence, % (95% CI)	Barriers	Facilitators	Proposed Interventions	BCW Proposed Intervention Functions
UHZ VAP prevention bundle overall	N.A.	- Physical opportunity (staffing/time) - Social opportunity (hierarchical structures)	- Psychological capability (comprehension and reasoning) - Reflective motivation (relevance of VAP, belief in preventability)	- Enablement (checklists) - Restrictions (protocols)	- Restriction - Environmental restructuring - Enablement
Continuous application of a sedation and weaning protocol	81 (74–87)	- Psychological capability (forgetfulness) - Physical opportunity (staffing/time)	- Social opportunity (coworkers)	- Enablement (checklists) - Restrictions (protocols)	- Restriction - Environmental restructuring - Enablement - Education - Training
Head of the bed elevation of ≥30°	27 (23–31)	- Physical capability (inability to estimate angle) - Psychological capability (forgetfulness) - Reflective motivation (lack of evidence) - Automatic motivation (conflict with patient's well-being) - Physical opportunity (side effects, infrastructure/equipment)	- Social opportunity (champions)	- Environmental restructuring (eg, bed with angle indicator) - Enablement (alarm system) - Enablement (checklists) - Restrictions (protocols)	- Restriction - Environmental restructuring - Enablement - Education - Training - Persuasion - Incentivisation - Coercion - Modelling
Oral decontamination with chlorhexidine mouth wash	41 (36–45)	- Automatic motivation (conflict with patient well-being) - Physical opportunity (infrastructure/ equipment, feasibility)	- Automatic motivation (habit) - Reflective motivation (belief in prevention measure)	- Environmental restructuring (eg, providing mouth wash in gel form)	- Restriction - Environmental restructuring - Enablement - Persuasion - Incentivization - Coercion - Modelling
Use of endotracheal tubes with continuous subglottic secretion drainage	88 (83–92)	- Physical opportunity (infrastructure/ equipment)	- Physical opportunity (infrastructure/equipment)	- Environmental restructuring (eg, tracheal tubes with suction port)	- Restriction - Environmental restructuring - Enablement
Hand hygiene according to the WHO 5 moments concept	N.A.	- Physical opportunity (staffing/time)	N.A.	N.A.	- Restriction - Environmental restructuring - Enablement
Use of non-invasive ventilation (NIV) whenever feasible	N.A.	- Reflective motivation (lack of evidence, disbelief in prevention measure) - Physical opportunity (competing priorities, staffing/time)	N.A.	N.A.	- Restriction - Environmental restructuring - Enablement
Periodic changes of ventilator tubing and filters	N.A.	N.A.	N.A.	N.A.	
Use of closed suction systems	N.A.	- Physical opportunity (infrastructure equipment)	- Physical opportunity (infrastructure equipment)	N.A.	- Restriction - Environmental restructuring - Enablement
Daily evaluation of stress ulcer prophylaxis to limit its use	N.A.	N.A.	N.A.	N.A.	

Note. BCW, behavior change wheel; N.A., not applicable. This table summarizes the adherence rates assessed by observation and reported barriers, facilitators, and proposed interventions mapped according to intervention functions of the BCW framework.[32]

adherence, both HCPs and the BCW framework suggested 2 main interventions, 'restructuring the environment' and 'enablement of HCP.'

VAP prevention measures were shown to be poorly executed by other investigators: Adherence to head of bed elevation or to daily sedation interruption, for example, was reported to be 25%–35%,[36–39] and 29%–56%,[40,41] respectively. In our study, we found good adherence for sedation vacation, but adherence rates may have been overly optimistic because a considerable percentage of patients were judged to have contraindications for this prevention measure and because some of these contraindications might have been relative. On the other hand, the interviews revealed that adherence to oral care with chlorhexidine was low due to poor documentation rather than missing execution. For the other 3 measured bundle elements, self-assessment of interviewees corresponded largely with the measured adherence. For another 3 of the 5 bundle elements not measured (ie, hand hygiene, NIV, and daily evaluation of stress ulcer prophylaxis), adherence was considered improvable by the interview participants (data not shown).

Semi-structured interviews identified 2 main facilitators for bundle adherence, both belonging to the BCW component 'reflective motivation.' First, VAP was perceived as a serious and common problem among ICU patients. Many interviewees, especially nurses, estimated VAP incidence at 50% of ventilated patients, corresponding to VAP rates of around 40% of studies applying the Clinical Pulmonary Infection Score (CPIS) criteria.[3,42] Second, HCPs perceived prevention measures to lower VAP rates by as much as 30%–80%, corresponding to 52% and 55% in scientific reports.[23,24] These noticeably accurate estimations might represent important prerequisites for protocol adherence.

Many of the barriers belonged to the BCW component 'physical capability.' HCPs were not satisfied with the quality of the equipment or regretted lack of specific devices (eg, tracheal tubes with a suction port) and staffing levels. From the existing literature, the unavailability of resources is a well-known barrier.[43,44] On the other hand, many HCPs raised concern over side effects of prevention measures (eg, head of bed elevation leading to increased need for catecholamines, belonging to component 'physical capability'). Some HCPs were subjectively concerned about the patient's well-being (eg, perception that head of bed elevation is uncomfortable for the patient, belonging to the component 'automatic motivation'). These findings have not been described elsewhere in the literature.

The BCW framework offers specific interventions to change behavior by linking sources of behavior to intervention functions (Table 1).[32] Notably, the proposals of interviewees matched those found in the BCW (Table 5). To approach the 2 main barrier components 'physical opportunity' and 'automatic motivation,' the BCW proposes 'environmental restructuring' and 'enablement'; the latter is considered to 'going beyond education and training and beyond environmental restructuring.'[32] This is consistent with our finding that HCPs asked for better equipment, checklists, and alerts. Of special interest, both the interviewees and the BCW proposed almost exclusively technical solutions. The benefit of technical solutions is supported by Cafazzo's 'hierarchy of intervention effectiveness.'[45] This management theory promotes system-focused or technological interventions over interventions that require conscious effort and change of behavior because the latter are notoriously more difficult to implement and sustain.[45,46] Concretely, our study revealed that the HCPs in our ICUs need (and request) a restructured work environment that provides forcing functions and automated or computerized processes.

Our study has several limitations. While we included all participating ICUs, the individual participants were recruited from a convenience sample of HCPs with an oversampling of nurses, and we cannot fully exclude the possibility that some opinions may have been missed. The quantitative measures were conducted in a pragmatic quality improvement context and included measurement points with small numbers of observations. Observations were not covered and adherence might have been overestimated because individuals modify their behavior when being observed (ie, the Hawthorne effect). Because this was a single-center study, the findings might not be generalizable to other settings. However, it covered 6 self-contained ICUs of different specializations and cultures.

In conclusion, adherence to 2 of 4 assessed prevention measures of our VAP bundle was assessed to be improvable, and barriers for adherence predominantly belonged to external reasons such as lack of adequate equipment or staffing or side effects of prevention measures. Mapping the inductively identified themes against the BCW framework pinpointed the need to 'restructure the environment' and to 'enable HCPs.' These findings were underpinned by the proposals of the interviewees, who also predominantly advocated for technical solutions to improve their adherence to VAP prevention measures. The BCW-informed mixed-method approach is an effective means for guiding infection prevention efforts. Further research is needed to assess the impact of these interventions on adherence rates.

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